TEAM TRAINING AND RETENTION OF SKILLS ACQUIRED IN ABOVE REAL TIME TRAINING ON A FLIGHT SIMULATOR

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Principal Investigator:
Syed Firasat Ali, Associate Professor, Aerospace Science Engineering Department, Tuskegee University, Tuskegee, AL 36088

Other Contributing Authors:
Dutch Guckenberger, SDS International Inc., Orlando, FL
Peter Crane, Air Force Research Laboratory, Mesa, AZ
Marcia Rossi, Tuskegee University, Tuskegee, AL
Mayard Williams, Tuskegee University, Tuskegee, AL
Jason Williams, Tuskegee University, Tuskegee, AL
Matt Archer, SDS International Inc. Orlando, FL

SUMMARY

Above Real-Time Training (ARTT) is the training acquired on a real time simulator when it is modified to present events at a faster pace than normal. The experiments related to training of pilots performed by NASA engineers (Kolf in 1973, Hoey in 1976) and others (Guckenberger, Crane and their associates in the nineties) have shown that in comparison with the real time training (RTT), ARTT provides the following benefits: Increased rate of skill acquisition, reduced simulator and aircraft training time, and more effective training for emergency procedures.

Two sets of experiments have been performed; they are reported in professional conferences and the respective papers are included in this report. The retention of effects of ARTT has been studied in the first set of experiments and the use of ARTT as top-off training has been examined in the second set of experiments. In ARTT, the pace of events was 1.5 times the pace in RTT. In both sets of experiments, university students were trained to perform an aerial gunnery task. The training unit was equipped with a joystick and a throttle. The student acted as a nose gunner in a hypothetical two place attack aircraft. The flight simulation software was installed on a Universal Distributed Interactive Simulator platform supplied by ECC International of Orlando, Florida.

In the first set of experiments, two training programs RTT or ARTT were used. Students were then tested in real time on more demanding scenarios: either immediately after training or two days later. The effects of ARTT did not decrease over a two day retention interval and ARTT was more time efficient than real time training. Therefore, equal test performance could be achieved with less clock-time spent in the simulator.

In the second set of experiments three training programs RTT or ARTT or RARTT, were used. In RTT, students received 36 minutes of real time training. In ARTT, students received 36 minutes of above real time training. In RARTT, students received 18 minutes of real time training and 18 minutes of above real time training as top-off training. Students were then tested in real time on more demanding scenarios. The use of ARTT as top-off training after RTT offered better training than RTT alone or ARTT alone. It is, however, suggested that a similar experiment be conducted on a relatively more complex task with a larger sample of participants.

Within the proposed duration of the research effort, the setting up of experiments and trial runs on using ARTT for team training were also scheduled but they could not be accomplished due to extra ordinary challenges faced in developing the required software configuration. Team training is, however, scheduled in a future study sponsored by NASA at Tuskegee University.

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800 Elkridge Landing Road
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RETENTION OF EFFECTS OF ABOVE REAL-TIME TRAINING

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Marcia Rossi, Tuskegee University, Tuskegee, AL

Peter Crane, Air Force Research Laboratory, Mesa, AZ

Dutch Guckenberger, SDS International Inc., Orlando, FL

Syed Firasat Ali, Tuskegee University, Tuskegee, AL

Matt Archer, SDS International Inc. Orlando, FL

Jason Williams, Tuskegee University, Tuskegee, AL

1.1 ABSTRACT

Above real-time training (ARTT) is an instructional strategy in which the pace of events in a real-time simulation is increased. University students were trained to perform an aerial gunnery task either in real-time or at 1.5 times real-time (ARTT). Subjects were then tested in real-time on more demanding scenarios either immediately after training, or two days later. Results show that students trained in real-time or using ARTT performed equally well on test trials and that the effects of ARTT did not decay more rapidly than real-time training. Further, students trained using ARTT required less clock time to achieve equal test performance as students trained using real-time simulation.

1.2 RETENTION OF EFFECTS OF ABOVE REAL-TIME TRAINING

Above real-time training (ARTT) is an instructional tool for use in real-time simulators. Kolf (1973) and Hoey (1976) document applications of ARTT at the National Aeronautics and Space Administration's (NASA) Dryden Flight Research Center that were aimed at improving test pilots' ability to keep up with the pace of events in test flights. Kolf notes that, "regardless of the type or amount of pre-flight simulator training accomplished by the pilot, the actual flight seems to take place in a much faster time frame than real time," (p. 1). Hoey (1976) reports that in the X-15 program, pilots typically spent ten hours in the simulator for each ten minutes of flight. Even with this preparation, pilots reported that, "It sure seems to happen faster in the real airplane," or, "I had the feeling that I was 'behind the airplane' ", (pp. 2 - 3). Hoey (1976) describes application of ARTT to a flight test program for remotely piloted vehicles (RPV). In this case, the training environment was exactly the same as the actual flight environment. Nevertheless, RPV pilots who used simulation at 1.4 times real time as final preparation before a flight reported being, "Less rushed and more confident," (p.18) than when using real-time training exclusively. A typical practice was to conduct 70% of training at real time with the last 30% at 1.4 times real time.

More recently, Schneider, Vidulich, & Yeh (1982) and Vidulich, Yeh, & Schneider (1983) used time-compression in developing training systems for air traffic controllers. The task for these controllers was to monitor an aircraft's flight path on a radar display. Actual aircraft would traverse 20 nautical miles and require approximately five minutes to complete an assigned turn. These researchers increased the apparent rate of time in the simulator to 20 times real time so that a turn would be completed in approximately 15 seconds. Vidulich, Yeh, & Schneider (1983) trained university students over four hours to perform a turn-point initiation task. A group of students who performed the task in real time experienced approximately 32 trials in four hours of training. A group performing the same task using ARTT at 20 times real time received approximately 260 time-compressed trials followed by only three or four real-time trials in four hours of training. All trainees were tested at real time for two hours. ARTT subjects showed significantly better performance at initiating turns properly. These authors assert that the ARTT improves training effectiveness by allowing many trials and training under a mild speed stress.

Guckenberger, Uliano, Lane, & Stanney (1993) conducted an experiment using 24 experienced F-16C pilots trained at real time or ARTT. All pilots then tested at real time. ARTT groups showed faster threat response than the group trained in real time and achieved significantly more bandit kills during real-time, test trials. Schneider (1989) proposed that the primary effect of time compression is to allow more training trials within a given period of clock time. In the air traffic control studies, subjects were given the same amount of training time in the simulator so that the ARTT subjects received more training trials. In contrast, Guckenberger et al. gave all subjects the same number of training trials so that the ARTT subjects received less training time than the students trained in real time. Since the pilots trained using ARTT performed better on real-time test trials than students trained in real time, Guckenberger et al.'s results indicate that ARTT has a beneficial effect beyond simply increasing the number of training events.

Crane and Guckenberger (1997) conducted two experiments to evaluate applications of ARTT for training air combat skills and emergency procedures. In the first experiment, experienced Air Force F-16 pilots practiced emergency procedures and air intercepts using conventional, real-time simulation or ARTT at 1.5 times real time. The pilots trained using ARTT received the same number of training trials but less clock time in the simulator as pilots trained in real time. All pilots were then tested in real time. Pilots trained using ARTT performed emergency procedures and defeated bandit aircraft significantly faster than pilots trained in real time. In the second experiment, student F-16 pilots practiced using air-to-air radar in real time or ARTT. Students trained using ARTT received more training trials in approximately the same amount of clock time as the students trained in real time. ARTT students performed better on a more complex real-time test than students trained in real-time. Crane and Guckenberger concluded that ARTT at 1.5 times real-time is more time efficient than conventional, real-time simulation and can improve performance by allowing more training events to be experienced within a given period of simulator time. ARTT also supported better real-time test performance for tasks requiring skilled performance in time and workload management.

In previous ARTT experiments, real-time transfer tests were conducted immediately after training. One hypothesis to explain the effect of ARTT is that trainees have adapted to a rapid pace of responding and, like sensory adaptation, this effect will rapidly decay with time. To assess whether effects of ARTT will be retained over a period typical of many training environments, performance of students using ARTT or real-time training was tested immediately after training or two days later. In addition, previous studies have been conducted using either a fixed number of training trials with ARTT trainees receiving less clock time in the simulator or, a fixed amount of clock time in the simulator with ARTT trainees receiving more training trials. Subjects in the present experiment were trained varying both simulated time and the number of training trials.

1.3 METHOD

This experiment used a 2 X 2 X 2 between subjects factorial design. The independent variables were real-time training (RT) vs. ARTT, 10 training trials vs. 15 training trials, and O-day retention vs. 2-day retention. Participants were randomly assigned to conditions in blocks of eight (i.e., one per condition). The experiment was conducted in three phases, familiarization, training and testing. For all participants, regardless of condition, familiarization and testing were conducted in real time. Only training trials involved real time vs. above real time.

Participants

Thirty-two undergraduate, university students (25 males, and 7 females) volunteered to participate. Volunteers received no financial remuneration or extra credit for their participation.

Equipment

The equipment used by the students consisted of four personal computers on Local Area Network (LAN). The software system produced by ECC International of Orlando, Florida is called Universal Distributed Interactive Simulation (UDIS), which is a turnkey DIS environment. The computers were configured as two student stations and two instructor-operator stations.

Student Stations. The student stations were equipped with a video monitor and joystick on the right and a throttle on the left. For this experiment, the student stations were configured as if the student were a nose gunner in a hypothetical two-place attack aircraft. The UDIS student stations operate in RT or ARTT as selected from the instructor's station. The virtual world in which the students were operating was created from digital terrain elevation data. Textures were then overlaid on top of the terrain to create out-the-window visual imagery.

Instructor-Operator Stations. Each IOS was used to initialize student stations and to provide real-time monitoring of student actions and interactions. The IOS also incorporated an interactive playback utility (IPU), which was used to play back previously recorded aircraft flight paths. Ownship flight paths plus the actions of friendly and enemy aircraft in this experiment were recorded and replayed using the IPU for the student acting as the gunner.

Flight Scenarios. Separate, three-minute flight scenarios were recorded for familiarization, training, and test. Scenarios used for familiarization were designed to be relatively easy and met the following criteria:

- There were approximately 15 targets presented during the flight.
- Each target were exposed for approximately eight seconds
- Target aircraft were in level flight at right angles and co-altitude to ownship
- No more than one target was in view at any time
- The student's attack aircraft flew straight and level
- Three emergency counter-measures (ECMs) were required.

Training flights consisted of two types: moderate or difficult; characteristics of these flights are described in Table 1. During training, all participants received three of the difficult flights, randomly ordered and placed within their prescribed number of trials. The remaining flights were of moderate difficulty. Testing consisted of three different difficult flights.

Table 1.1 Characteristics of moderate and difficult scenarios

Scenario variables	Type of scenario	
	Moderate	Difficult
Number of targets presented within three minute flight	19 - 24	39 - 43
Duration of each target's exposure	5 - 7 seconds	4 - 5 seconds
Target aspect	Level flight at right angles and co-altitude to ownship	Targets at all headings and altitudes
Number of targets in view at any moment	≤ 2	≤ 4
Ownship motion	Turns < 90° of heading change with<45° bank	Turns up to 180° with 90° bank plus barrel rolls
ECM responses required	4 - 6	6 - 9

Procedure

After signing an informed consent agreement, participants were asked to complete a one-page background survey, which asked questions regarding handedness, age, gender, and number of hours of video games played per week, as well as experience in marksmanship.

Familiarization. Participants were seated in front of the computer monitor and informed that they would receive familiarization instructions that would describe the task and the use of the computer and its controls. The head-up display (HUD) that would be present during the actual flights was demonstrated. The HUD included symbology indicating whether a gun or missile was activated, and the slewable weapon's cursor. Their mission was to, "act as a nose gunner on an attack aircraft whose mission is to fire a missile at a large transport aircraft that is flying near an airport." The arrack aircraft's flight path was previously recorded and not under student control. The student's joystick slewed the weapon's cursor; the throttle control was not functional although buttons on the throttle were used in the ECM task. Students were also instructed that en route to the airport they would encounter a number of threats. Their task was to identify the type of threat, and determine whether a missile or gun would be required to destroy it. Helicopters required a gun, deployed by a trigger squeeze, whereas airplanes, including the transport aircraft, required a missile deployed by a button press. A flip of a switch on the joystick would change the weapon from guns to missiles. In addition, participants were required to determine whether the aircraft was a bandit or a friendly aircraft by its color; friendly targets were dark colored helicopters and light colored airplanes while bandits were light colored helicopters and dark colored planes. They were instructed to shoot all enemy aircraft and not to shoot friendlies.

Participants were also informed of two other controls, the "identify friend or foe" (IFF) button, and the ECM buttons. Specifically, if they needed help in identifying an aircraft, they could push the IFF button and after a two-second delay would hear an audio signal identifying the aircraft. Friendly targets produced a harsh sound, while bandit targets produced a pleasant ding ding sound. Participants also were told that when a bandit has locked on to them, they would hear a high-pitched beeping sound. They were to employ ECM immediately by pushing one pinky button under the trigger on the right handle and then pushing the large round gray button on the left handle. For all procedures, the experimenter requested that the student perform the procedure after describing it.

Participants were informed of point values for each procedure or task; points could be gained by shooting enemies with the correct weapon: +2, proper ECM activations: +1, and destroying the C-17: +5. Points could be lost by killing a friendly: -4, missing a bandit: -2, and killing a bandit with the wrong weapon: -2. Scores were summed, divided by total possible, points for that flight, and multiplied by 100. If all procedures were carried out correctly, the maximum score would be 100%. Participants were told that when each flight ended, ownship position would freeze and feedback regarding performance would be displayed on the screen. At this point, the instructor would review the performance and then start the next trial.

Participants were then instructed to put on their headsets and prepare for the first familiarization trial by placing their hands on the proper controls. The instructor stated that on the first trial, he or she would coach the participant through the first half of the flight. After that point they would be available to answer questions. Coaching consisted of identifying the target for the participant, and then instructing on which weapon to use. When an ECM event was about to occur, the instructor told the participant to be prepared for it, and if the participant had trouble in executing the procedure, the instructor described it and/or pointed to the controls for him or her. All participants received the same flight for their first familiarization flight. During the remainder of familiarization, the instructor simply answered questions at the end of each flight and reviewed the participant's performance, identifying what the participant had done correctly and incorrectly. Participants continued receiving familiarization trials selected randomly until they had reached at least 30% correct on two consecutive trials.

Training. Training proceeded in the same fashion as familiarization, except that some subjects received ARTT for all training trials, while others received RT training. In addition, some subjects received ten trials while others received fifteen. Also, there was no verbal contact between participant and instructor during a trial, but feedback was reviewed after each trial.

Testing. Prior to testing, participants were told that on the next few flights they would not receive feedback regarding their performance until all three flights were completed. Participants in the zero delay condition were asked to take a five-minute break between training and testing. Participants in the two-day retention condition were told that they were finished for the day. They were reminded of their time to return, and asked to please return as scheduled. At the completion of testing, subjects were debriefed and told their final scores

1.4 RESULTS

Performance scores on test trials were analyzed with a 2 x 2 x 2 between-subjects analysis of variance (ANOVA). Overall, performance on test trials was not affected by simulated time during training, RT vs. ARTT ($F < 1$), retention interval, zero vs. two (day ($F < l$), or the number of training trials, 10 or 15 ($F < 1$). The transition from training to the more demanding real-time test trials was assessed using a mixed design ANOVA with trial as the repeated factor. There is a significant interaction between training vs. test performance and real-time training vs. ARTT, $F(12,276) = 6.44$, $p. < .01$ (see Figure 1.1). Mean performance scores during training for students using real-time simulation are significantly higher than scores for students trained using ARTT, $F(1,23) = 43.5$, $p. < .01$. Performance scores of the two groups are not significantly different for test trials, $F < 1$.

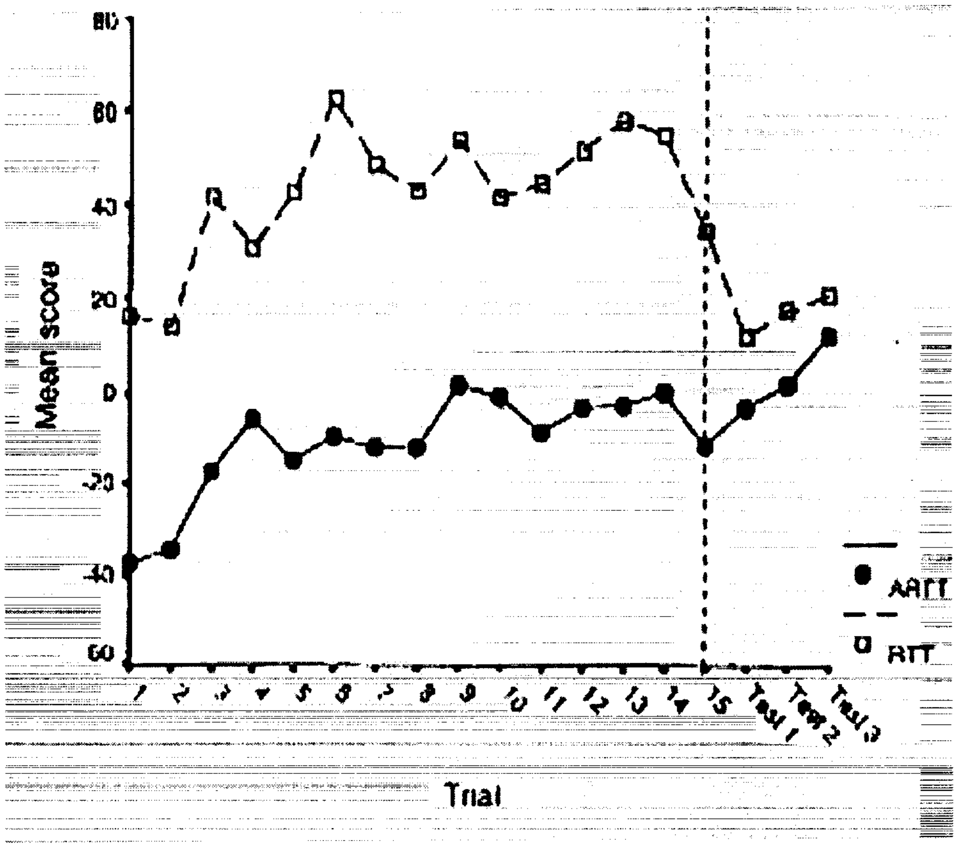

Figure 1.1 Mean training and test scores for students trained in real time and ARTT.

1.5 DISCUSSION

This experiment was designed to assess the effects of three training variables on performance of a demanding, real-time task: simulated time, number of training trials, and retention interval. Previous research on ARTT employed a procedure in which training was immediately followed by test. It is possible that the effect of ARTT is to adapt the trainee to a rapid pace of responding and that this adaptation would fade quickly with time. To evaluate this hypothesis, test trials were presented either immediately after training or two days later. Length of the retention interval by itself did not affect test performance and did not interact with simulated time. There is no evidence from this experiment that skills developed using ARTT are less lasting then real-time, training. Also, for this task adding five extra training trials, in real time or using ARTT, did not affect performance on test trials.

Two major effects of ARTT can be seen in Figure 1.1. First, performance scores during training for students using ARTT are depressed compared to performance scores of students trained using real-time simulation. Performing a challenging task such as the one developed for this experiment is made more difficult by performing it quickly. Real-time simulation was more effective than ARTT for helping trainees learn to master this task. The second effect of ARTT can be seen in the transition from training to test. The ARTT concept was initially developed at NASA based on the experience of test pilots that actual flying was more demanding than flying a simulator. The idea was that ARTT should reduce the severity of transitioning from the simulator to the aircraft by training pilots to fly under higher demand conditions. This hypotheses was supported in that performance of students trained using ARTT was not significantly affected when they transitioned from training scenarios to the more difficult test scenarios that were presented in real time. The scores of students trained in real time, however, were lower/'or on test trials than for training trials.

Overall, the results of this experiment demonstrate that as an instructional tool, ARTT has both costs and benefits. The cost is reduced student performance during training. The benefits are improved time efficiency of training and better transition to increasing task demands. Current research efforts at Tuskegee University are aimed at developing training strategies that will incorporate ARTT into a more comprehensive set of instructional tools.

1.6 CONCLUSION

University students were trained to perform an aerial gunnery task with RT or ARTT and tested either immediately after training or two days later. Results of this experiment show that effects of ARTT did not decrease over a two day retention interval and that ARTT was more time-efficient than real-time training in that equal test performance could be achieved with less clock-time spent in the simulator. In addition, when students transitioned from training scenarios to more demanding test scenarios presented in real time, performance of students trained in real-time degraded while the performance of students trained using ARTT was unaffected.

1.7 ACKNOWLEDGEMENTS

The research efforts described in the paper were supported by grant number NAG4-133 from NASA Dryden Flight Research Center to Tuskegee University. Kongolo Mulumba and Rodriques Walker generated and recorded most of the flight scenarios for familiarization and training. Professor Kay Stanney suggested the protocols for the retention experiments. Thanks are also due to Mayard Williams, Traron Moore, Don Angelo Bivens, Quionna Caldwell, and Alison Foster.

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ABOVE REAL TIME TRAINING AS TOP-OFF

TRAINING FOR A GUNNERY TASK

ON A FLIGHT SIMULATOR

by

Mayard Williams

Graduate Student

Aerospace Engineering Department

Tuskegee University

Tuskegee, AL 36088

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Faculty Member Responsible for Work

Signature

This paper has been reviewed and approved for presentation by Dr. S.F. Ali,
AIAA Faculty Advisor

Signature

2.1 ABSTRACT

A 3x2 mixed factorial experiment was conducted to compare three different training programs for a simulated gunnery task. A participant acted as the weapons officer in the pre-programmed simulated flights. The task required identifying friendly and bandit aircraft, selecting the appropriate weapon, locking and destroying the bandit aircraft, activation of emergency counter measures for self-defense. Every participant received 12 minutes of familiarization and 36 minutes of training. Every participant was tested immediately after training and also seven days after training.

The three training programs are termed as Real Time Training (RTT), Above Real Time Training (ARTT), and Real & Above Real Time Training (RARTT). In RTT events on the simulator occurred at their normal pace for the complete 36 minutes of training. In ARTT events occurred at a pace 1.5 times the normal pace for the complete 36 minutes of training. The RARTT consisted of 18 minutes of RTT followed by 18 minutes of ARTT. The test scores indicate that the transfer of training is highest in the RARTT condition. In all three programs, the seventh day retention tests revealed no deterioration in the acquired training.

2.2 INTRODUCTION

Above Real Time Training (ARTT) is the training acquired on a real time simulator when it is modified to present events faster than normal. The works of Kolf [1] and Hoey [2] suggest that above real time training for pilots would lead to significant increase in the effectiveness of flight training although it results in reduced simulator fidelity. Kolf [1] notes that " regardless of type or amount of pre-flight simulator training accomplished by the pilot, the actual flight appears to take place in a much faster time frame than real time (App. A1)." In an experiment, Kolf[1] modified the M2-F3 Lifting Body Simulator to obtain the pace of events 1.5 times their pace in real time. Three pilots who had already flown the M2-F3 expressed that the modified simulator felt exactly like the aircraft. Hoey [2] reports that measurements of test pilots operating remotely piloted vehicles, shows that the stress level, physical level and mental states of the pilots are more influenced by the strong sense of responsibility and anxiety, instead of fear or personal danger when compared to past data taken in flight. The mental state can be approximately simulated without stressful conditions by increasing the simulated rate of time passage.

While exploring the possible benefits of ARTT, Guckenberger, et. al[3] placed the objectives of NASA Dryden Flight Research Center and Air Force Human Systems Center's Technical Planning Integrated Product Team (HSC, TPIT) in perspective. They proposed that the Air Force training may derive the following benefits from ARTT: increased task performance, increased trainee retention of skills, increased situation awareness, decreased real time work load, decreased real time stress, increased rate of skill acquisition, reduced simulator and aircraft training time, and more effective emergency procedures training. Crane and Guckenberger [4] have reported that pilots trained using ARTT performed emergency procedures and defeated bandit aircraft significantly faster than pilots trained in real time.

Rossi et al [5] trained university students on a gunnery task to compare ARTT verses RTT, 10 trials verses 15 trials for training, and immediate testing verses testing after two days retention. Based on their work, Rossi et al have hypothesized that the use of ARTT as top-off training after RTT would result in more effective training. Their hypothesis is addressed in the present study by offering mixed RTT and ARTT to university students. In different contexts, mixed training had been studied by Guckenberger, Uliano, and Lane[6] and by Crane and Guckenberger[4]. In the present study, a 3x2 mixed factorial experiment was conducted to include the use of ARTT as top-off training after RT. The three training conditions were RTT, ARTT, and RARTT. In the RTT condition, real time training has been provided for the complete training duration. In the ARTT condition, above real time training was provided for the complete training duration. In the RARTT condition, real time training was provided for the first half of the training duration and above real time training was provided for the next half of the training duration, so that ARTT is used as top-off training. Three different groups of participants were individually trained and tested to compare the effectiveness of the three different training programs. Every participant was tested immediately after training and also seven days after training.

2.3 PARTICIPANTS

Twenty-one students in a freshman aerospace engineering course at Tuskegee University volunteered as participants to obtain the training and to be tested in the research program. The participants did not have any formal experience of gunnery tasks or flying. Some participants, however, indicated experiences of playing video games.

2.4 APPARATUS

The training unit was comprised of two IBM PC compatibles, one used as the instructor's station and the other as a student's station. The student stations was equipped with a joystick and a throttle. The flight simulation software for a simplified A-10 model simulator was installed on a Universal Distributed Interactive Simulator (UDIS) platform supplied by ECC International of Orlando. The A-10 like airplane flight was initialized at 10,000 ft above ground level at 250 knots. In different flights, different scenarios of friendly and bandit airplanes and helicopters were encountered while a participant was seated as a weapons officer in front of the computer screen. The flight scenarios were developed in house for a prior study conducted by Rossi et al[5]. Joy stick and throttle buttons were configured for identifying targets, activating Emergency Counter Measures (ECMs), and selecting and firing weapons. After completing each flight the statistics on the participants' performance and percentile score in the flight were displayed on the screen. In the RTT every flight was completed in 3 minutes; in ARTT the pace of events was 1.5 times the normal pace and every flight was completed in 2 minutes. Details on apparatus may be seen in Rossi et al[5].

2.5 PROCEDURE

The assignment of participants to each of the three training programs or conditions: RTT, ARTT, and RARTT were made randomly. Every participant signed a consent form and completed a brief background survey. Every participant was provided with a brief description of the apparatus and the task. Every participant completed four familiarization trials each of three minutes duration in real time. Every participant in the RTT condition completed twelve training flights of three minutes each. Every participant in ARTT condition completed 18 training flights of two minutes each. Every participant in RARTT condition completed six flights of three minutes each in real time and nine flights of two minutes each in above real time. Nine different flight scenarios were used for training; they were randomly presented to a participant, and in some cases repeated to complete the training duration of 36 minutes for a participant. Flight scenarios were presented either in real time or in above real time mode. In the present study a factor of 1.5 was selected for above real time operation. Therefore, a flight of three minutes in real time required two minutes in above real time. Typical familiarization, training, and test flights conducted by a participant with respective scores are given in Table 1.

2.6 RESULTS

RARTT and one fixed training time of 36 minutes being the between participant factors, and two retention periods immediate and seven days being within participant factor. The dependent variables have been performance scores, completeness, and retention. All the tests were conducted in real time. Only three flights of three minutes duration each were used for testing. For immediate testing every participant conducted three flights assigned in random order. For the seventh day testing too, every Data were analyzed as a 3x2 mixed factorial experiment, with three training conditions RTT, ARTT, and participant conducted three flights assigned in random order. On the seventh day, however, before conducting the test flights, every participant conducted one familiarization flight of three minutes duration. Twenty-one participants were trained in the program. For six of the participants the training of the program was questionable either they did not return or they returned later than the seven days, therefore the data for fifteen participants have been reported and discussed here.

Figures 1 and 2 provide the test scores of immediate testing and Figures 3 and 4 provide the test scores of the seventh day testing. Figures 1 and 3 have test scores of individual participants presented in groups of three to represent three different training conditions. Figures 2 and 4 have average scores of five participants in each of the three training programs and average scores of three best performances in each of the three training programs.

It is proposed that an acceptable comparison of training programs or educational programs can be based on a few best performing trainees or students. With such an outlook the average scores of three best performances in immediate testing and in seventh day testing reported in Figures 2 and 4 respectively offer acceptable comparison. The performance clearly suggests that the transfer of training is highest in the RARTT program or in the training program with ARTT used as top-off training. In all three training programs, the seventh day retention tests reveal no deterioration in the acquired training. Analysis of variance[7] is applied to five participants in each program and to the three best performances in each program. The variance values and the F ratios are presented in Table 2 a & b. When the number of participants are the same in two different training programs, then the F ratio is the ratio of variance of test scores of all the participants in the two programs to the average of variance of test scores of participants considered program-wise. For five participants in each program, the F ratios are less than one; they indicate that the three different training programs do not offer significantly different transfer of training. The F ratios based on three best performances, however, reveal some significant differences. For comparison between RTT and ARTT, the F ratio of less than one suggests that RTT alone and ARTT alone do not offer significantly different transfer of training. For comparison between RARTT and RTT, the F ratio is 1.83 and for comparison between RARTT and ARTT, the F ratio is 1.87. Therefore, from analysis of variance applied to the same day tests, we may infer that the use of ARTT as top off training after RTT offers significantly better training in comparison to ARTT alone or RTT alone. The F ratios of the seventh day tests are all less than one. The large variance in the seventh day tests of RTT is noticeable. It would, however be worthwhile to verify the inference based on same day tests by conducting an experiment requiring relatively more complex training tasks and by acquiring sample data with a larger number of participants.

In addition to the inference based on the best three performances, the traditional statistical inferences based on the sample size of five are obtained by using the sign test. Relevant quantities for the sign test are provided in Table 3. For the sign test, the null hypothesis implies no significant difference between the two modes of training which are compared. For the three different comparisons shown in Table 3, the null hypothesis may be rejected if the error α is allowed to be 0.18. The sign test inference and analysis of variance inference are same for comparing RTT and RARTT and for comparing ARTT and RARTT, but they are not same for comparing RTT and ARTT.

TABLE 2.1

Typical Familiarization and Test Flights With Respective Scores

	Fam. Flights	Training Flight	Test Flight
Enemies encountered	9	11	26
Enemies shot down with correct weapon*	8(16/18)	8(16/22)	16(32/52)
Enemies shot down with wrong weapon*	1(-2/0)	0	0
Enemies missed*	0(0/0)	3(-6/0)	10(-20/0)
Friendlies encountered	6	10	12
Friendlies shot down*	1(-4/0)	0(0/0)	0(0/0)
ECM required	3	6	9(9/9)
ECM activated*	3(3/3)	5(5/6)	9
IFF inquiries on friendly	0	0	1
IFF inquiries on enemy	0	0	0
Final objective met*	1(5/5)	1(5/5)	1(5/5)
Total scored points	18	20	26
Maximum possible score	26	33	66
Percent score	69.5	60.6	39.39
* Earned Score/Maximum possible score are given in parentheses			

FIG. 2.1 SAME DAY TEST SCORES FOR RTT, ARTT, AND RARTT

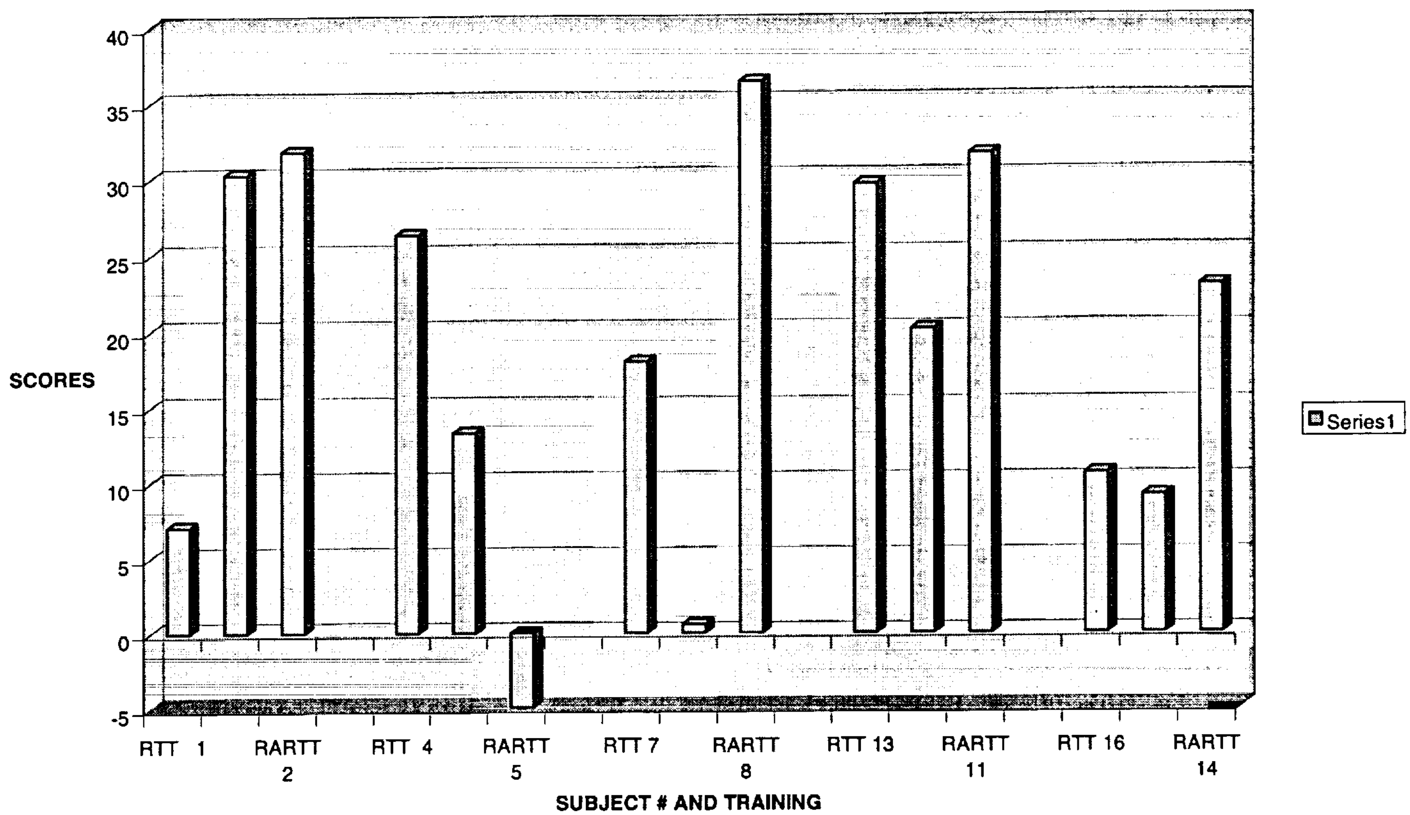

FIG. 2.2 SAME DAY AVERAGES AND TOP 3 AVERAGES

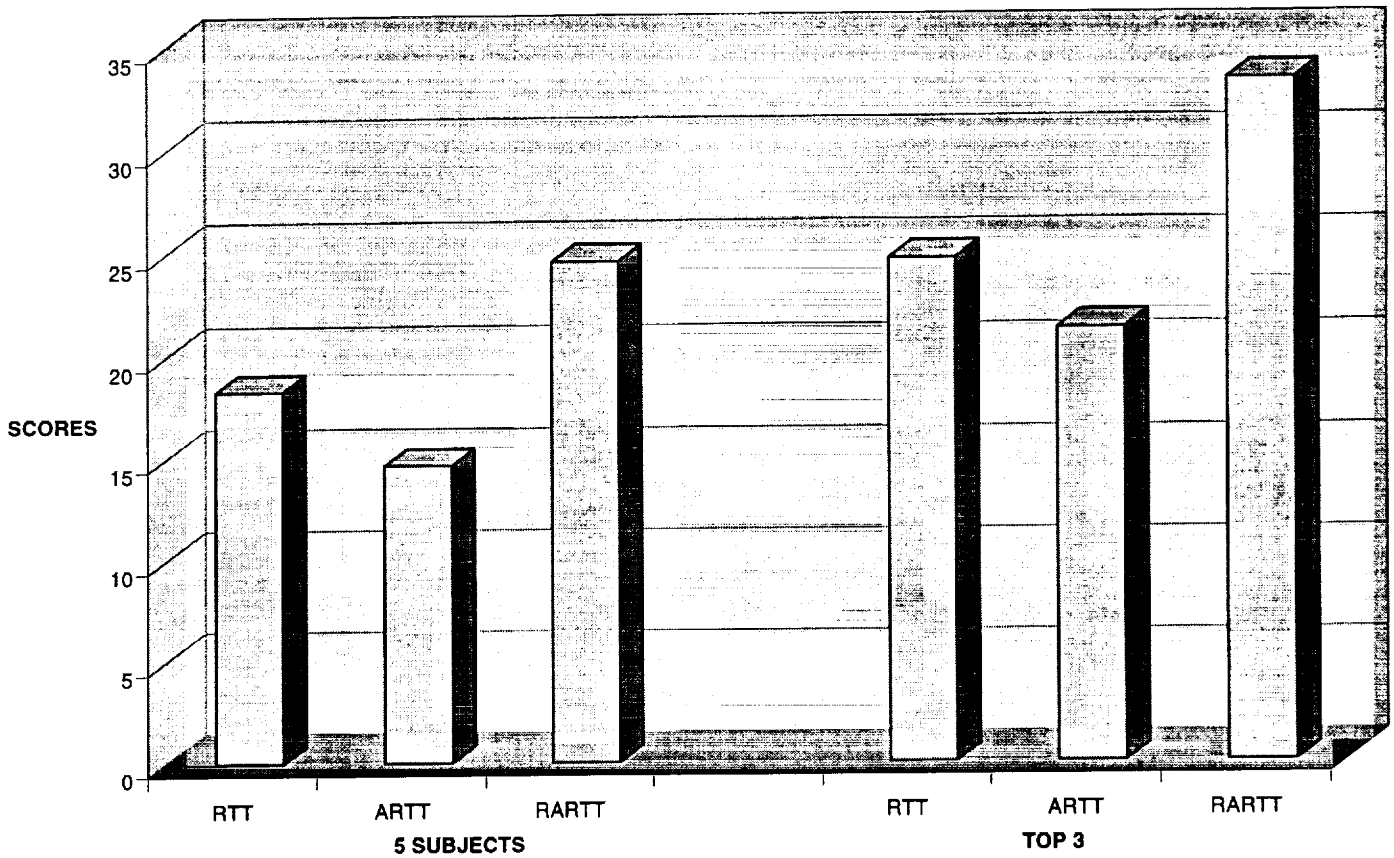

FIG. 2.3 SEVENTH DAY TEST SCORES RTT, ARTT, AND RARTT

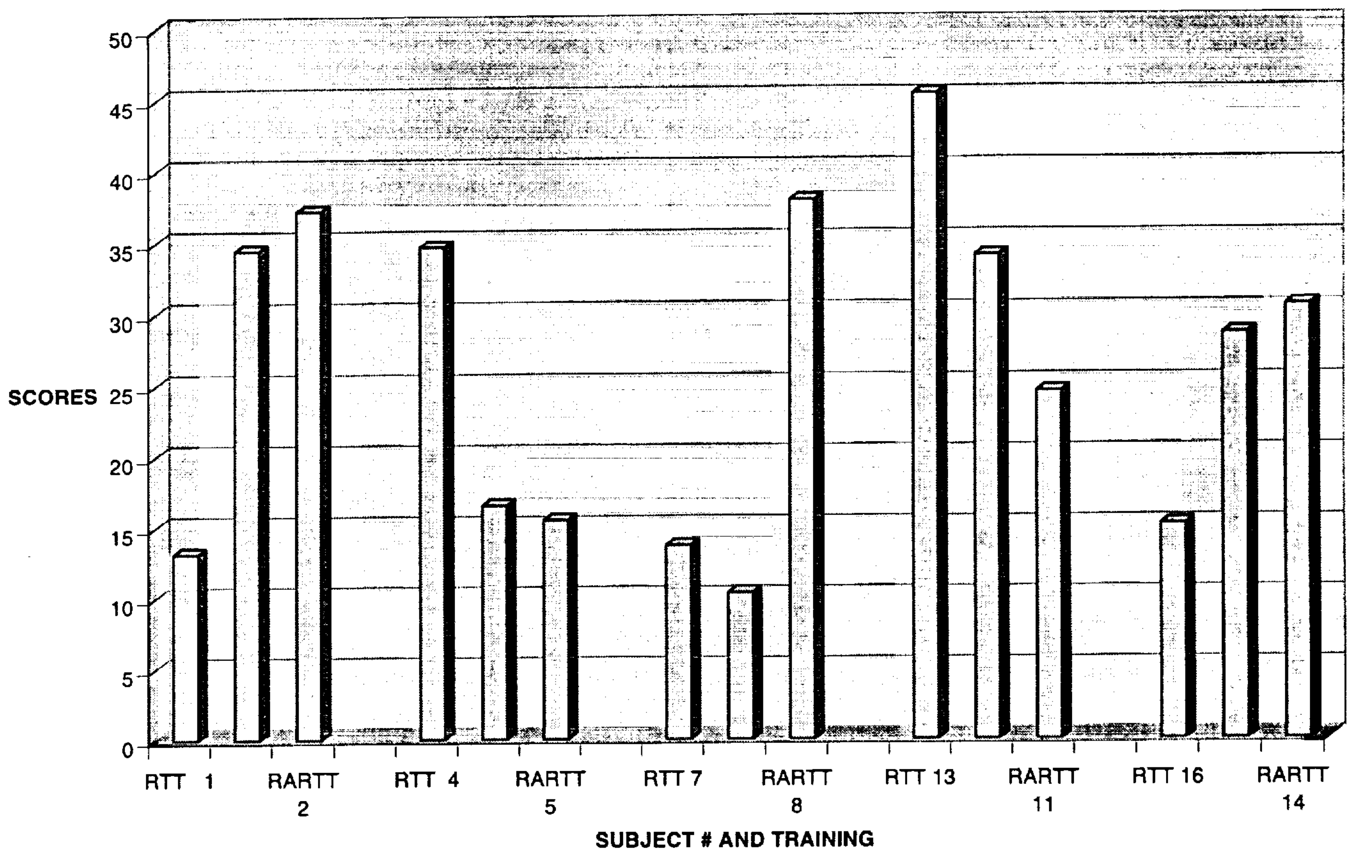

FIG. 2.4 SEVENTH DAY AVERAGES AND TOP 3 AVERAGES

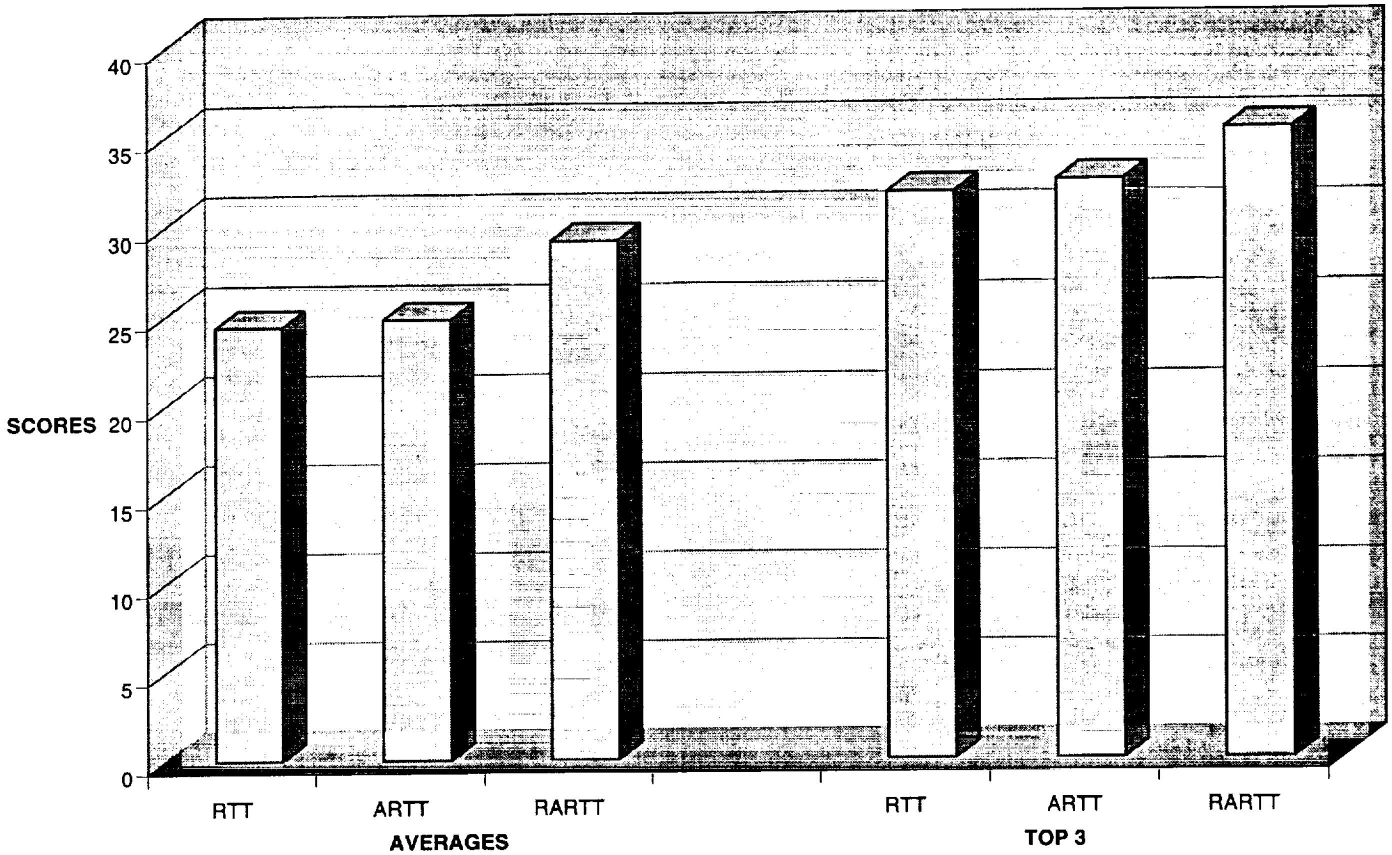

Table 2.2a: Analysis of Variance For 3 Groups Based on Top 3 Performances
Same Day Test
RTT, ARTT, RARTT

Training Type	Five Scores For Each Type					Average	Variance Per type	Average Of Var.	Total Var. Per group Of two types	F Ratios/ Retention
RTT	29.6	26.3	18	7.08	10.6	18.31	94.36	110.19	101.63	0.92
ARTT	30.2	20.1	13.3	0.57	9.09	14.66	126.01			same day
RTT	29.6	26.3	18	7.08	10.6	18.31	94.36	185.55	172.63	0.93
RARTT	36.4	31.8	31.6	23	-4.9	23.57	276.74			same day
ARTT	30.2	20.1	13.3	0.57	9.09	14.66	126.01	201.38	201.03	1
RARTT	36.4	31.8	31.6	23	-4.9	23.57	276.74			same day
7th Day Test										
RTT	45.32	34.64	15.15	13.2	13.69	24.39	217.22	167.26	148.71	0.89
ARTT	34.44	33.99	28.52	16.5	10.34	24.76	117.3			7th day
RTT	45.32	34.64	15.15	13.2	13.69	24.39	217.22	152.385	141.62	0.93
RARTT	37.89	37.18	30.44	24.5	15.51	29.1	87.55			7th day
ARTT	34.44	33.99	28.52	16.5	10.34	24.76	117.3	102.425	96.29	0.94
RARTT	37.89	37.18	30.44	24.5	15.51	29.1	87.55			7th day

Table 2.2b: Analysis of Variance For 3 Groups on Top 3 Performances
Same Day Test
RTT, ARTT, RARTT

Training Type	Top 3 Scores For Each Type			Average	Variance Per type	Average of Variance	Total Var. Per group Of two type	F Ratios/ Retent.
RTT	29.58	26.32	18	24.63	35.66	54.19	46.85	0.86
ARTT	30.24	20.13	13.29	21.22	72.72			same day
RTT	29.58	26.32	18	24.63	35.66	21.53	39.5	1.83
RARTT	36.39	31.77	31.59	33.25	7.4			same day
ARTT	30.24	20.13	13.29	21.22	72.72	40.06	75.46	1.87
RARTT	36.39	31.77	31.59	33.25	7.4			same day
7th Day Test								
RTT	45.32	34.64	15.15	31.77	234.03	122.45	98.07	0.8
ARTT	34.44	33.99	28.52	32.32	10.86			7th day
RTT	45.32	34.64	15.15	31.77	234.03	125.47	103.98	0.82
RARTT	37.89	37.18	30.44	35.17	16.91			7th day
ARTT	34.44	33.99	28.52	32.32	10.86	13.89	13.55	0.98
RARTT	37.89	37.18	30.44	35.17	16.91			7th day

Table 2.3: Sign Test

TRAINING	1	2	3	4	5	x in ••••x•	••value to reject null
RTT (y1)	7.08	26.32	18	29.58	10.56		
ARTT (y2)	30.24	13.29	0.57	20.13	9.09		
Sign of y1-y2	-	+	+	+	+	1.34•	0.18
RARTT (y1)	31.77	-4.9	36.39	31.59	22.98		
RTT (y2)	7.08	26.32	18	29.58	10.56		
Sign of y1-y2	+	-	+	+	+	1.34•	0.18
RARTT (y1)	31.77	-4.9	36.39	31.59	22.98		
ARTT (y2)	30.24	13.29	0.57	20.13	9.09		
Sign of y1-y2	+	-	+	+	+	1.34•	0.18

2.7 CONCLUSION

A study on the comparison of three different training programs for a simulated gunnery task is reported. The three training programs are termed as RTT, ARTT and RARTT. In RTT or real time training, events on the simulator occurred at their normal pace for the complete 36 minutes of training. In ARTT or above real time training events occurred at a pace 1.5 times the normal pace for the complete 36 minutes of training. The RARTT consisted of 18 minutes of RTT and 18 minutes of top-off training in the ARTT mode. The data of five participants in each mode of training were reported. The Analysis of variance, however, has been applied to the three best performances in each training mode. It is inferred that the use of ARTT as top-off training after RTT offers significantly better training in comparison to ARTT alone or RTT alone. The results are encouraging toward conducting a similar experiment on a relatively more complex task with a sample of a larger number of participants. In all three training programs, the seventh day retention tests revealed no deterioration in the acquired training, provided a brief re-familiarization with the task is allowed.

2.8 ACKNOWLEDGEMENTS

In a research program at Tuskegee University sponsored by NASA DFRC under grant NAG4-133, Rossi, Guckenberger, Crane, Ali, Williams, and Archer (1999) have studied Above Real Time Training and its Retention; The present study is conducted under the same research program. Based on their work, Rossi et al (1999) have hypothesized that the use of ARTT as top-off training after RT would result in more effective training. Their hypothesis is addressed in the present study. The author wishes to thank Rossi et al for their guidance.

The author is also thankful to Lateef Pelt, Rodrigues Walker, Kongolo Mulumba, and Quiona Caldwell. Lateef randomized the sequencing of flights for training of different participants and supervised several training sessions. Kongolo and Rodrigues developed most of the flight scenarios used for familiarization and training. Quiona a psychology student helped determine the type of method used in the experimental design. Thanks are also due to the twenty- one Aerospace Engineering Freshmen of the 1998 fall semester who volunteered to be trained and tested for the gunnery task on the flight simulator.

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